





Review

Scientific Development of Educational Artificial Intelligence in Web of Science

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Abstract: The social and technological changes that society is undergoing in this century are having a global influence on important aspects such as the economy, health and education. An example of this is the inclusion of artificial intelligence in the teaching–learning processes. The objective of this study was to analyze the importance and the projection that artificial intelligence has acquired in the scientific literature in the Web of Science categories related to the field of education. For this, scientific mapping of the reported documents was carried out. Different bibliometric indicators were analyzed and a word analysis was carried out. We worked with an analysis unit of 379 publications. The results show that scientific production is irregular from its beginnings in 1956 to the present. The language of greatest development is English. The most significant publication area is Education Educational Research, with conference papers as document types. The underlying organization is the Open University UK. It can be concluded that there is an evolution in artificial intelligence (AI) research in the educational field, focusing in the last years on the performance and influence of AI in the educational processes.

Keywords: artificial intelligence; bibliometric analysis; documentary analysis; scientific mapping; web of science

1. Introduction

The social and technological changes that the society of this century is experiencing are influencing globally important aspects such as the economy, health or education [1]. There is no doubt that the development of this society is promoted, in large part, by technological advances and their practical implications in society. In this sense, the challenges that education systems are currently facing require constant adaptations and reforms to offer a balanced and adjusted response that responds to the real needs of citizens [2]. For these reasons, the relationship between education and technology is becoming stronger and more intense, with a growing market that reaches up to 8 trillion dollars by 2020 [3]. Different technologies can offer tools and instruments that collaborate and facilitate the adaptation of teaching–learning processes to the real needs of students [4]. Among these technologies we can find virtual and augmented reality; cloud computing; and digital media, such as images, video or audio [5].

One of them is artificial intelligence (AI). This can be defined as the combination of algorithms determined with the intention of generating machines that have the same capabilities as people [6]. Taking into account what has been indicated by various authors, we can find four types of artificial intelligence, among which are (a) recreational machines, which are purely reactive, without the capacity to form memories or to use their experiences to make decisions [7]; (b) limited memory, which can look at the past, allowing the analysis of data developed with anteriority [8]; (c) theory of mind, in which

machines are able to form not only representations of physical reality, but also of the reality of people [9]; and (d) self-awareness, this last stage of AI allows machines to be conscious and; therefore, able to predict the emotions of others [10]. In addition, the relationship between the 5G network and artificial intelligence must be borne in mind. On the one hand, the 5G network makes it possible to have a large amount of data stored in the cloud. On the other hand, AI makes it possible to establish a more stable network connection for citizens and companies [11].

Faced with this technological panorama, artificial intelligence (AI) applied to education opens up in a powerful way [12]. Although its beginnings can be established around the 1970s [13], the most current definition [14] (p. 2) conceives it as “computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction and the use of data for complex processing tasks”. From this perspective, AI applied to education can be understood as an interdisciplinary research area involving the methods and results of the learning sciences, such as Education, Neuroscience, Psychology, Linguistics, Sociology and Anthropology. This interdisciplinary action aims to develop inclusive, adaptable, personal, flexible and effective learning environments that complement and optimize traditional education and training [15].

The most recent literature in the educational field [16–21] clearly identifies the key issue of the training process in which AI offers a more important contribution. In this review, evaluation is the training process par excellence where the impact of AI is promoting more changes. Among the implementations that it enables, AI are intelligent tutoring systems [22]; games and simulations that capture and interpret incremental movements on the fly [23]; exploration of texts on students’ writing or natural language for possible semantic analysis [24,25]; recording and analysis of the flow of clicks that predict student success [26]; and peer reviews via computer [27]. From this perspective, AI provides added value to training platforms, allowing the creation of a personalized teaching–learning environment through the recognition and comparison of patterns, decision-making and the most opportune choice at all times, the execution and sequential control of tasks and activities, as well as planning and problem solving according to the data collected from the interaction with the student on the platform [28]. From this new training paradigm, the role of the teacher continues to be essential [16] for the preparation of the classes and the maintenance of the course content. These will be adjusted or modified based on the data collected on the platform due to its interaction with the content and the students. It will also allow the teacher to more closely and realistically monitor the student’s progress by having all the data updated in real-time. As can be seen, human thought and action are still needed in the educational practice of ontologies that define the world of systematized knowledge and give meaning to its means of representation. This remains the role of the teachers and the work of the students.

In relation to the educational stages where AI is most impacting education, studies show that training in higher education is, by far, where it is being implemented the most [4,29–32], for example, in areas as representative as medicine [33,34], engineering, mathematics, economics [35], languages [36] and online supervised machine learning courses [37]. As can be seen, the penetration of AI in more humanistic areas, such as the arts or letters, is scarce because this technology is still weak in mental abilities such as creativity, innovation, critical thinking, problem solving, socialization, leadership, empathy, collaboration and communication [38]. For these authors, arts and humanities majors may experience increased enrollment and become more popular with students, as these areas are less susceptible to the “invasion of AI”. In contrast to this idea, we find the areas of science and engineering are where their enrollments can be drastically reduced, as these works are replaced by robots supported by AI.

As can be seen, the implications of AI for education have their benefits and pose a series of short- and long-term challenges. Among the benefits is the support and help to the teachers to adapt the classes according to the profile of the students, and the interests of the students can be stimulated by exposing them to various contents and tasks according to the answers they are providing. In addition, AI can help teachers with homework by proposing more personalized activities based on the correct response rate and the mistakes they are making. On the other hand, the same intelligent system can alert the teacher to a question or proposed tasks that are wrongly answered by a large number of students [18].

This allows the teacher to rectify and modulate the contents and the proposed tasks. Another benefit of implementing AI in the training of students is that they can benefit from supplementary tutoring by virtual assistants supported by AI [39]. Another potential benefit of AI is the ability to provide feedback to teachers and students on the success of the course by tracking and monitoring student progress and thus notifying teachers of any problems with student performance [40]. In this sense, learning based on trial and error is not as discouraging as in other learning models, since AI itself learns frequently through the trial and error method and; therefore, is considered a system optimal for learning as it provides students with a fairly judgment-free learning environment. Moreover, AI tutors themselves can suggest solutions for improving student performance [41].

On the other hand, [12] poses a series of challenges in incorporating AI into education. The first has to do with the costs of implementing AI in the educational system. The initial outlay for software acquisition and cloud support is very costly, in addition to ongoing employee training and training of the AI system itself. The second is related to the clash of cultures in organizations. Any change can be understood as suspicious given that there are several technological options and it is difficult to decide which are the possible options and the most appropriate route of application. Computer machines are nothing more than cognitive prostheses that allow collaborative relationships to be established between humans and their calculation tools. Another challenge that AI poses has to do with the ethical component of using large amounts of data from people. The use made of them, such as their handling, remains in the air while the viability of this technology is discussed within traditional pedagogies [42,43].

2. Justification and Objectives

In this research, the concept of AI is analyzed from a bibliometric perspective of the documents indexed in the Web of Science (WoS) database. In this case, the novelty of this study focuses on presenting a documentary analysis to the scientific community using an innovative technique such as scientific mapping. Likewise, a dynamic and structural evolution of the selected construct is carried out. To carry out a relevant analytical process, other reported studies from the impact databases that have used this same analytical technique have been taken as a model [44,45].

The basis of this study focuses on analyzing the importance and projection that AI has acquired in the WoS scientific literature. As far as our knowledge reaches, no study has been found on the topic addressed that has carried out a scientific mapping of the term in question. Therefore, it was decided to carry out this work of an exploratory nature in order to offer new results in this field of knowledge, reduce the gap produced in the literature on this art and provide the results presented here as a starting point for other researchers interested in AI. Therefore, this research focuses on the following objectives:

- To know the performance of scientific production indexed in WoS on “AI”;
- To concrete the scientific evolution on “AI” in WoS;
- To discover the most decisive issues about “AI” in WoS;
- To determine the most incident authors on “AI” in WoS.

3. Materials and Methods

3.1. Research Design

To achieve the defined objectives, bibliometrics was used as the most appropriate research methodology for this type of study. Bibliometry has great potential to search, record, analyze and predict scientific literature on a given question [46]. In order to effectively deploy this methodology and its different actions, the considerations of the experts in this field of study were taken into account [47].

At a higher level of methodological concretion, this research focused on an analysis of co-words [48] and of certain bibliometric indicators, such as the h, g, hg and q2 indices, proposed by different experts to complement this type of studies [49,50]. The research deployment allowed for generating maps with nodes to specify the performance and locate the terminology subdomains concerning AI [51].

Additionally, the implementation of these analytical actions allowed a thematic development of the concept in WoS [52].

3.2. Procedure and Data Analysis

The research was planned in different processes in order to carry out an adequate study, thus reducing the possibility of finding biases derived from poor performance. The moments in which this study was structured are the following:

1. To choose the database for documentary analysis (WoS);
2. To select keywords (AI);
3. To construct the search equation ("AI" [TITLE] in the categories of "Education Educational Research", "Education Scientific Disciplines", "Education Special" and "Psychology Educational");
4. To perform the search action in the title, abstract and keywords metadata of the documents registered in WoS.

All of these performances produced a total of 411 publications. To refine the search process, different criteria were established. The following were taken into account as exclusion criteria: The documents published in the year 2020 (for not having finished the year); repeated or poorly indexed documents in WoS. Inclusion criteria that were delimited: Year of publication (all production except 2020); language ($x \geq 5$); publication area ($x \geq 15$); type of documents ($x \geq 15$); organizations ($x \geq 4$); authors ($x \geq 3$); sources of origin ($x \geq 9$); countries ($x \geq 20$); the four most cited documents ($x \geq 17$). These criteria produced a final analysis unit of 379 publications to analyze.

The entire procedure was reflected in the following flow diagram based on the protocols of the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) matrix (Figure 1).

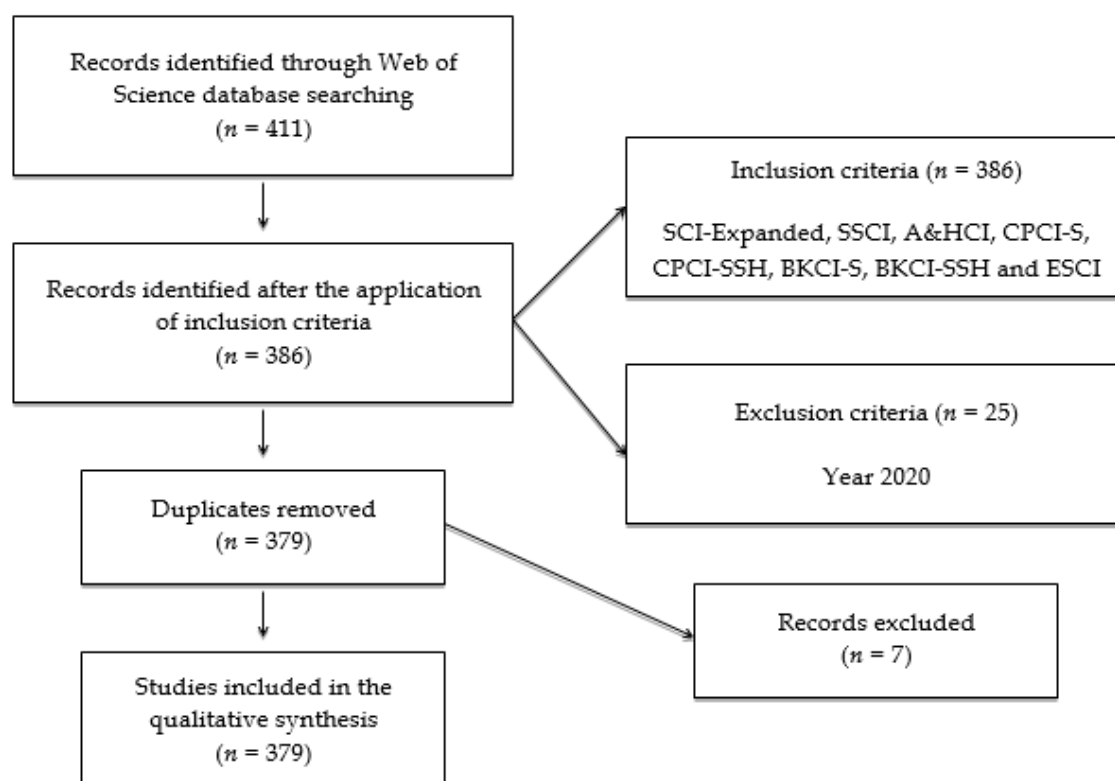


Figure 1. Flowchart according to the PRISMA Declaration.

The analysis of the documents recovered from WoS was carried out using three tools [53]. Firstly, Analyze Results and Creation Citation Report were used to report and analyze the data

referring to the year, authorship, country, type of document, institution, language, medium and most cited documents. Subsequently, the Science Mapping Analysis Tool (SciMAT) was used to study the structural and dynamic development of publications on AI at the longitudinal level. For the correct use of this last software, the guidelines of the specialists were followed [54]. With SciMAT, different actions were carried out to carry out the analysis of co-words [55,56]:

- **Recognition:** In this process, the keywords of the reported WoS documents were analyzed ($n = 728$). Then, the design of the co-occurrence node maps was made. Next, a standardized network of co-words was generated and the most significant keywords were found ($n = 698$). Finally, the most common topics and terms were defined with a clustering algorithm.
- **Reproduction:** In this process, different thematic networks and strategic diagrams were prepared, articulated in four areas (upper right = motor and relevant themes; upper left = rooted and isolated themes; lower left = disappearing or projected themes; lower right = themes of poor development and transversal). All this was derived from the principles of centrality and density.
- **Determination:** The reported results allowed for knowing the year in which the first works on AI (1956) were published. Based on the collected literature, an analytical range was established that covers from 1956 to 2019. This range was articulated from different time periods to study the literature. This allowed us to analyze the projection of the nodes in different time sections. Specifically, 3 periods were established (P1 = 1956–2006; P2 = 2007–2016; P3 = 2017–2019). These intervals were configured taking into account a similar volume of documents as the main criterion. However, for the analysis of authorship, only one period was configured that covers all the studied temporality of the term in question (PX = 1956–2019). To determine the strength of association between the intervals, the number of keywords in common between the different configured periods was taken into account.
- **Performance:** This last process involved the application of certain production indicators along with their corresponding inclusion criteria (Table 1).

Table 1. Production indicators and inclusion criteria [44].

Configuration	Values
Analysis unit	Keywords authors, keywords WoS
Frequency threshold	Keywords: P1 = (1), P2 = (2), P3 = (2) Authors: PX = (2)
Network type	Co-occurrence
Co-occurrence union value threshold	Keywords: P1 = (1), P2 = (1), P3 = (1) Authors: PX = (2)
Normalization measure	Equivalence index
Clustering algorithm	Maximum size: 9; Minimum size: 3
Evolutionary measure	Jaccard index
Overlapping measure	Inclusion Rate

4. Results

4.1. Scientific Performance and Production

Scientific production on AI in the educational field reports a total of 379 documents in the WoS database. Its beginnings date back to 1956. From that year until today the production has been irregular. From 1956 to 2017 the volume of production was very low. Only in the years 2018 and 2019 did this subject of study arouse the interest of the scientific community (Figure 2).

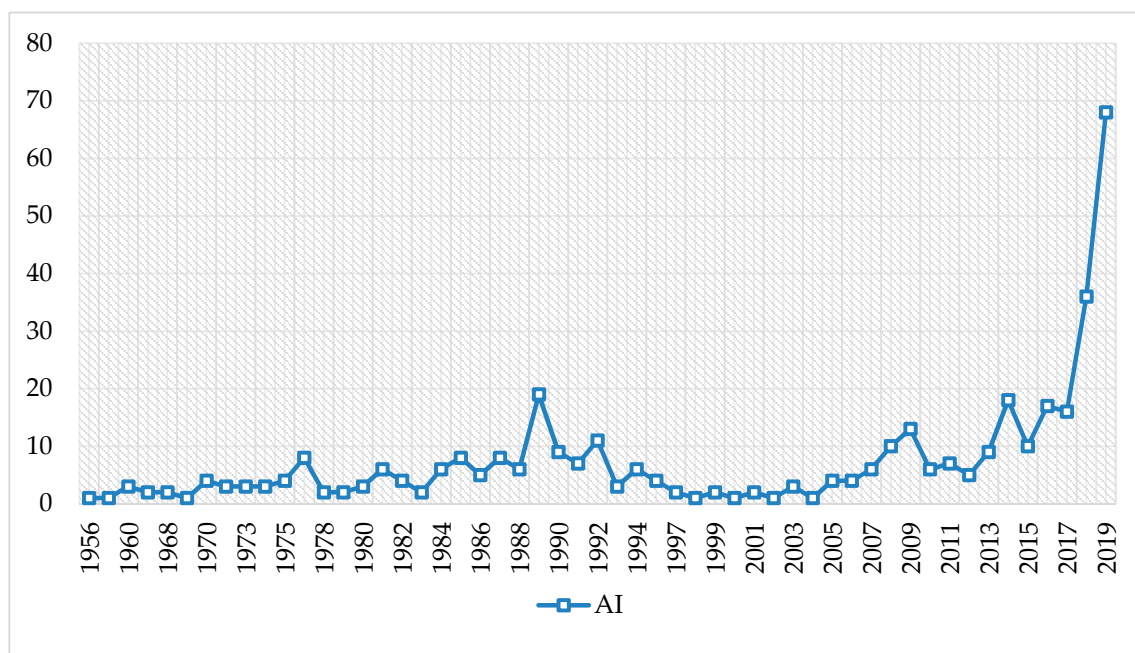


Figure 2. Evolution of scientific production.

The language used by the scientific community to show the results on the use of AI in the educational field is English. The rest of the languages are far apart (Table 2).

Table 2. Language of AI publications.

Languages	<i>n</i>
English	359
Russian	14
Spanish	6

The publication area where studies in this field of research are collected is Education Educational Research. It is followed, although at a considerable distance, by the area of Education Scientific Disciplines (Table 3).

Table 3. AI publication areas.

Areas	<i>n</i>
Education Educational Research	288
Education Scientific Disciplines	96
Computer Science Interdisciplinary Applications	60
Psychology Educational	31
Engineering Electrical Electronic	27
Computer Science AI	19

The document types preferred by the scientific community to show their findings are the proceedings paper, although it is closely followed by the research articles (Table 4).

The reference institution for studies on AI in the educational field is the Open University UK. The rest of the institutions are not far away, and there are a large number of institutions that are interested in this line of research (Table 5).

Table 4. AI document types.

Document Types	<i>n</i>
Proceedings Paper	144
Article	120
Book Review	80
Editorial Material	31
Book Chapter	17

Table 5. AI organizations.

Organizations	<i>n</i>
Open University UK	10
Indiana University System	6
Indiana University South Bend	4
National Centre of Scientific Research	4
State University System of Florida	4
Universidades Federal de Santa Catarina UFSC	4
University of Edinburgh	4
University of Malta	4

The author with the highest production volume is Blandford, A.E. He is followed by a group of researchers with very close production levels (Table 6).

Table 6. Most prolific AI authors.

Authors	<i>n</i>
Blandford, A.E.	4
Bondarovskaya, V.M.	3
Cumming, G.	3
Drigas, A.S.	3
Mamychev, A.Y.	3
Moye, J.N.	3
Oprea, M.	3
Silapachote, P.	3
Srisiphab, A.	3
Wolfer, J.	3

One of the most widely published journals in this field of study is *Voprosy Psikhologii*. It is followed by the journal *Computers and Education* (Table 7).

Table 7. AI Source of origin.

Sources	<i>n</i>
<i>Voprosy Psikhologii</i>	14
<i>Computers and Education</i>	10
E-learning and software for Education	9
Proceedings of the International Conference on Virtual Learning	9

The country of reference in studies on AI in education is the United States. It is followed by China, but at a very considerable distance (Table 8).

The most more cited document on AI in education is Devedzik's (2004), with a total of 26 citations. It is closely followed by the work of Parton (2006), with a total of 24. It stands out that the volume of quotes is truly low in this field of study, which shows that, to date, this line of research has yet to be exploited (Table 9).

Table 8. Countries of AI documents.

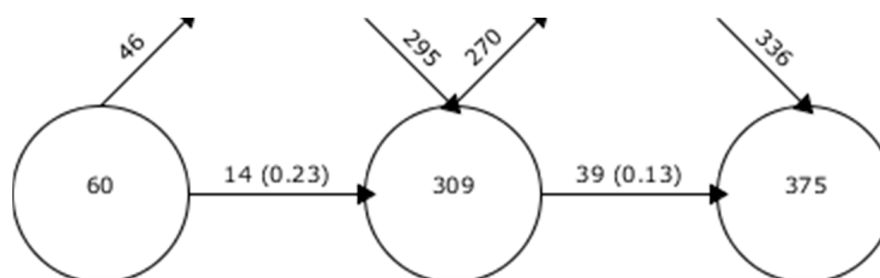
Countries	<i>n</i>
USA	90
China	36
England	31
Romania	23

Table 9. Most cited articles.

References	Citations
Devedzik, V. Web Intelligence and artificial intelligence in Education. <i>Educational Technology and Society</i> 2004, 7, 29–39.	26
Parton, B.S. Sign language recognition and translation: A multidisciplinary approach from the field of artificial intelligence. <i>Journal of Deaf Studies and deaf Education</i> 2006, 11, 94–101, doi:10.1093/deafed/enj003.	24
Nagy, J.; Burch, T. Communities of Practice in Academe (CoP-iA): understanding academic work practices to enable knowledge building capacities in corporate universities. <i>Oxford Review of Education</i> 2009, 35, 227–247, doi:10.1080/03054980902792888.	23
Wartman, S.A.; Combs, C.D. Medical Education Must Move from the Information Age to the Age of Artificial Intelligence. <i>Academic Medicine</i> 2018, 93, 1107–1109, doi:10.1097/ACM.0000000000002044.	17

4.2. Structural and Thematic Development

The temporal development of keywords in this field of study provides information on the level of coincidence of keywords between contiguous temporal periods. It also shows the keywords that are part of a specific time interval, those that leave a period and those that are added to it. As can be seen in Figure 3, the level of coincidence is relatively low. Especially between the second and third period. This indicates that there is no established line of study on this subject. Another noteworthy aspect is the number of key words from the first period. Although it covers a relatively wide time spectrum, from 1956 to 2006, the number of keywords is very low. This shows that the results of the first investigations were not shown in research articles, or in the documents that presented the data there were no keywords that brought together the most relevant aspects of the study.

**Figure 3.** Continuity of keywords between contiguous intervals.

The academic performance compiles the most relevant topics of each of the time intervals. In this case, said relevance is shown by means of various bibliometric indicators, among which the h index, the g index, the hg index and the q2 index, among others, stand out. In the first period (1956–2006), there is not one theme that stands out from the rest, due to the relatively low bibliometric indicators. Only the “artificial-intelligence” theme stands out, taking into account the g index and the hg index. In the second period (2007–2016), the most relevant themes are “system” and “artificial-intelligence”. In the third period (2017–2019), something similar to the first period will happen again. In this case,

taking into account the hg and q2 indexes, the “artificial-intelligence” theme can be highlighted. In other words, in all the periods the most relevant thing was the technology applied (Table 10).

Table 10. Thematic performance in AI.

Interval 1956–2006						
Denomination	Works	Index h	Index g	Index hg	Index q ²	Citations
Expert-system	1	1	1	1	1	1
Artificial-intelligence	3	1	2	1.41	1.73	4
Intelligence-agent	1	1	1	1	3.87	15
E-learning	1	0	0	0	0	0
Pedagogical-agent	1	1	1	1	5.1	26
Image-processing	1	1	1	1	2.45	6
Basic-science	1	1	1	1	1	1
Intelligent-tutoring-system	1	1	1	1	1.73	3
Interval 2007–2016						
Denomination	Works	Index h	Index g	Index hg	Index q ²	Citations
System	5	3	4	3.46	4.24	25
Artificial-intelligence	15	3	4	3.46	3.46	27
E-learning	4	1	1	1	1	1
Probability-distribution	2	2	2	2	5.48	19
Problem-solving	2	1	2	1.41	1.73	4
Interval 2017–2019						
Denomination	Works	Index h	Index g	Index hg	Index q ²	Citations
Support	4	2	2	2	2	4
Technology	5	2	2	2	2.83	6
Performance	6	2	2	2	2.83	10
Artificial-intelligence	15	2	3	2.45	3.46	13
Management	2	0	0	0	0	0

The various strategic diagrams, distributed by time bands, show the most relevant issues for the scientific community in each of these periods (Figure 4). The Callon index is used for this purpose. This indicator shows the relationship between the thematic networks. Both the strength of the external relationship (centrality) and the internal relationship (density).

It is possible to indicate that there is no theme, which is repeated as the driving theme, in the three established time periods. In all of them, the themes vary. In the period 1956–2006, the motor themes were “expert-system”, related to “psychology”, “therapy”, “ATMS”, “simulation”; “gaming”, “computers”, “counselling” and “programming”; and “basic-science”, related to “nosological-models”; “truth-maintenance-systems”, “causality” and “medical-ontologies”. At this time, studies on AI in the educational field were oriented towards the systems used to apply AI, in addition to the educational models used with this technology.

In the second period (2007–2016), the driving themes are “system”, related to “mathematics”, “intervention”, “fuzzy”, “intelligent-tutoring-systems”, “neural-networks”, “robotics”, “diagnosis” and “children”; and “probability-distribution”, related to “evaluation” and “concept-maps”. In this time interval, the research is oriented to aspects more related to the educational field, with may be the systems used for intervention and evaluation of pedagogical actions.

In the third period (2017–2019), only “performance” appears as the main theme, which is related to “deep-learning”, “science”, “active-learning”; “simulation”, “education”; “assessment”, “machine-learning” and “higher-education”. In this period the interest lies in the student’s performance, focusing on the development of active learning. At this time, there is also a lack of unknowns, so it is not possible to establish a forecast of possible future lines of research in this field of study.

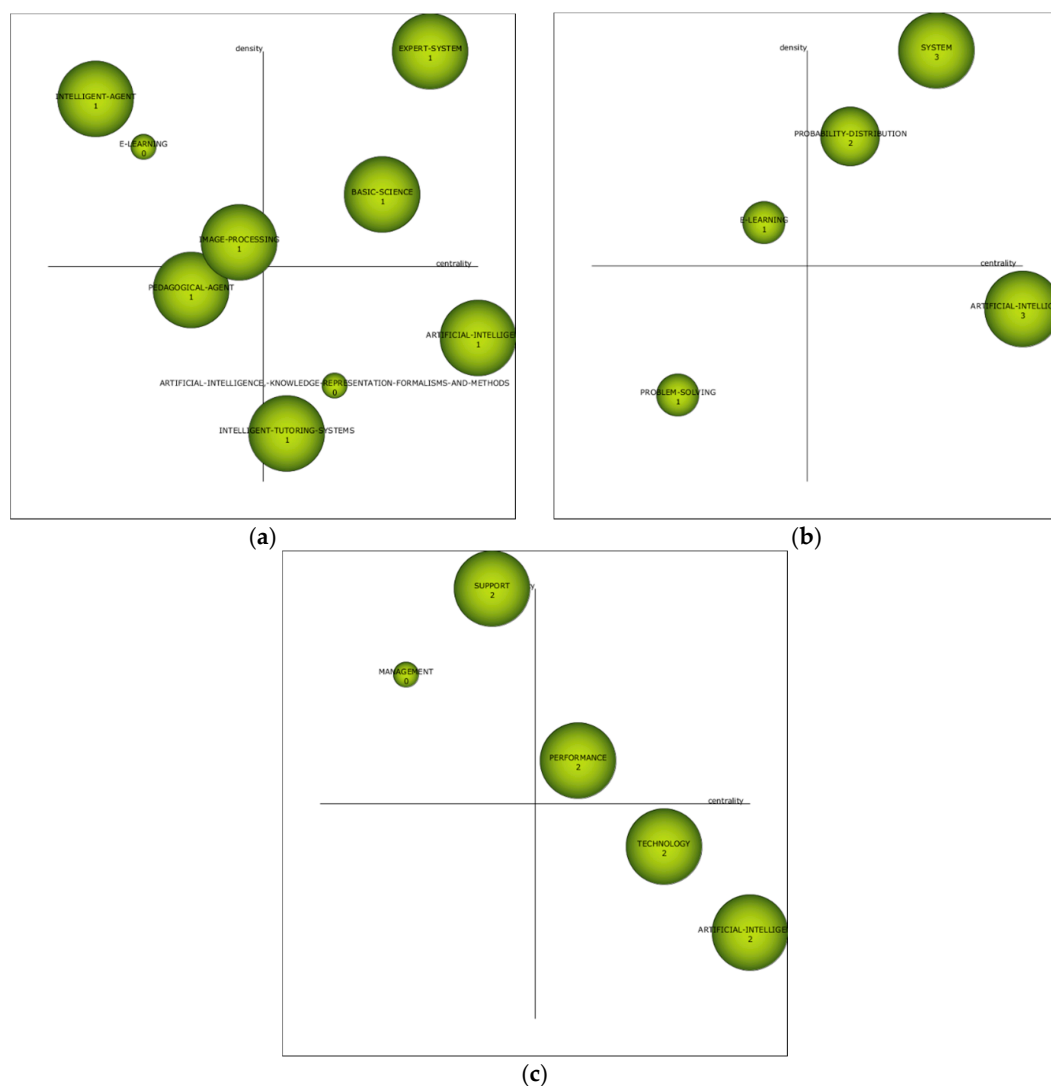


Figure 4. Strategic diagram by AI index-h. Note: (a) Range 1956–2006; (b) Range 2007–2016; (c) Range 2017–2019.

4.3. Thematic Evolution of Terms

The temporal evolution of the themes indicates the relationship and the strength of association between various themes of contiguous temporal periods. To show this relationship, Jaccard's index is taken into account. The relationship is generated if both themes share a certain number of key words or themes. The more they share, the stronger the link. The connections are represented by a broken line, if the relationship is by keywords; or a continuous line, if the connection is by themes. The thickness of the lines indicates the strength of the association. The thicker the line, the greater the relationship.

According to the data shown in Figure 5, there is a conceptual evolution of the subject of study, focused mainly on the subject of "artificial-intelligence". It can also be seen that there are very few connections between the various themes, which marks the scarcity of key words or coinciding themes between the different lines of research. In other words, there is no relationship between the researches carried out. This is due to the lack of research in this field of study. Probably, according to the evolution of production in the last two years, research on AI in education will begin to establish more established and clearer lines of research. The only reading that can be obtained from the production offered so far is the evolution of interest in this field of study. In the first years these focused on technological resources. In recent years it has focused on performance and the influence of AI on teaching–learning processes.



Figure 5. Thematic evolution by h-index.

4.4. Authors with the Highest Relevance Index

Considering the authors, Midoro, V. stands out as a relevant figure in this field of study and is considered the driving force (Figure 6).

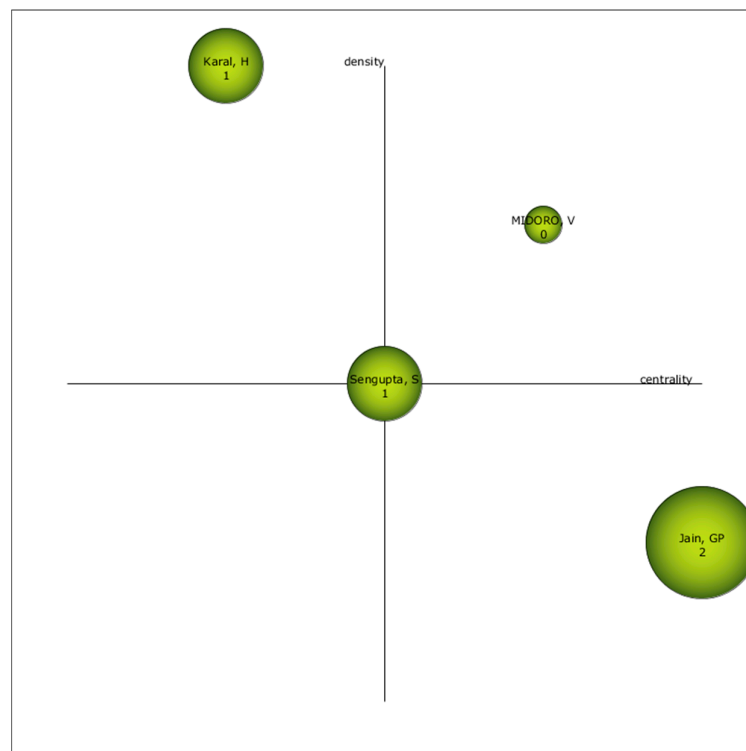


Figure 6. Strategic author diagram of the entire production.

5. Discussion

The technological advances that are currently being generated, with the implications they have for society, pose a great challenge in the educational field. New educational legislation and regulations are constantly being created to try to respond to the new socio-labor demands [1,2]. There is no doubt that educational technologies are a great resource, they are tools and instruments that facilitate the development of didactic processes. In fact, virtual and augmented reality is, in itself, an inexhaustible source of digital resources that can help all types of students, from normalized students to those with specific needs for educational support [3]. It offers the possibility of using the cloud, as well as making endless digital media available to students [4,5]. Obviously, teachers in the face of this virtual reality need specific training so that these technological tools are properly introduced, offering students all their potential.

However, not only does virtual reality makes its way daily in the field of education, but also the so-called AI applied to education [12–14]. Although it constitutes an area of interdisciplinary research that allows many possibilities, there is a symbiosis, for example, between linguistics and neuroscience [26]. In other words, it is an extremely attractive field to be able to interrelate teaching processes with new technologies from a highly innovative approach. In turn, this allows the creation of inclusive learning environments, that is, flexible, adaptable, effective and personalized, depending on the needs of the students [15].

Undoubtedly, as has been observed, the field in which AI provides the greatest advances is evaluative [16,21,24]. Therefore, the possibilities offered by this technological resource are very beneficial, since it provides added value compared to the traditional education system, allowing the customization of teaching environments and their development to be similar [23,25,27]. Thus, the teaching role in this new paradigm is key, from the initial didactic planning processes to the development of the contents and their evaluation. However, it is true that these technologies are a support in the educational process but can never be a substitute for the teaching role. They contribute to student learning and offer many possibilities that allow a more personalized and personalized educational advancement for each student. On the other hand, of all the stages offered by the educational system, the field of higher education is the one that best seems to be adapting to these technologies and where the best results are obtained [4,29–32,39–41]. Especially, in teacher training it is a highly attractive and useful resource because it allows to relate content, develop concepts, establish relationships, correct tasks, tutoring processes supported by virtual assistants, etc. [12,27,42,43]. Like all educational resources, AI requires good training for its teaching staff, a high initial investment for the acquisition of software and support in the cloud and ethical issues, as they have been exposed in a developed way in the state of the art.

Thus, in this investigation, a total of 379 documents dating from 1956 to the present day were analyzed. Although it is observed that the evolution of production has been quite irregular, the language of greatest development is English. The most significant publication area is Education Educational Research, with conference papers as document types. The underlying organization is the Open University UK and the author with the most production is Blandford, A.E. However, the author who stands out as the most relevant is Midoro, V. The publication source is Voprosy Psikhologii and the most productive country we found is the USA. To this must be added that the most cited work is that of Devedzik (2004), with a total of 26 citations.

Note that, in relation to the evolution of keywords, the level of coincidence is substantially low, that is, between the second and the third period almost no coincidence is observed. This is an indicator of the lack of a consensual and accepted line of study on this topic. Therefore, this research contributes to making its analysis and dissemination more attractive in the epistemological community of Education and Education Sciences, more specifically. On the other hand, the number of keywords from the first period stands out. The time limit is wide, ranging from 1956 to 2006, with which we are talking about a 50-year period in which the number of keywords is quite low. For this reason, the results of the first investigations were not included in scientific research articles or scientific documents, since there were not enough keywords that

brought together the most notable aspects of the study. Thus, we found a significant and relevant fact that shows, again, the need and relevance of this research in the field of education.

As for the thematic performance, the first period, between 1956 and 2006, is noteworthy, in which, once again, within those 50 years, no theme is observed that stands out in relation to the rest. This is due to how low the bibliometric indicators are. The “AI” theme only stands out if we consider the *g* index and the *hg* index. However, the second period, between 2007 and 2016, is the one that contains the most relevant topics, around the “system” and “artificial-intelligence”. Finally, the third period, which ranges from 2017 to 2019, shows something similar to what happens in the first period. Only if we take into account the *hg* and *q2* indexes does the “artificial-intelligence” theme stand out. This shows that in all the periods the most notable was the applied technology itself. For this reason, AI allows many advantages in relation to other types of educational technology.

The strategic diagrams show that the first period (1956–2006) has major motor themes, such as, for example, “expert-system”, related to “psychology”, “therapy”, “ATMS”, “simulation”; “Gaming”, “computers”, “counseling” and “programming”; and “basic-science”, related to “nosological-models”; “truth-maintenance-systems”, “causality” and “medical-ontologies”. This period also shows that studies on AI in education were more focused on the systems used to apply AI, and that AI again offers a much wider range of possibilities than traditional educational models.

On the other hand, the second period (2007–2016) is an indicator of the emergence of new thematic engines, such as the “system”, related to “mathematics”, “intervention”, “fuzzy”, “intelligent-tutoring-systems”, “neural-networks”, “robotics”, “diagnosis” and “children”; and “probability-distribution”, related to “evaluation” and “concept-maps”. Thus, this second period makes it possible to detect that the research and studies carried out are directed more towards aspects of educational change, such as the systems used for intervention and the evaluation of pedagogical actions. This shows a marked trend that is based on new denominative needs.

Finally, the third period (2017–2019) is characterized by having “performance”, related to “deep-learning”, “science” and “active-learning”, as its basic theme; “simulation”, “education”; “assessment”, “machine-learning” and “higher-education”. That is to say, the most significant thing that we found in this period, and that closes these conclusions, is that the most notable denominative and thematic interest focuses on student performance, in their interest in the development of active and participatory learning. Although, there is a lack of unknowns, which means that a diachronic study cannot be drawn up to advance possible lines of research.

Thus, the conceptual evolution of the theme of this study has been based on the “artificial-intelligence” theme. The analysis of the data carried out allows us to affirm that the few connections that have been found between the different topics show a shortage of keywords and a lack of topics related to the different lines of research. For this reason, we affirm that there is no relationship between the researches that has been carried out and hence the main incentive and innovative nature of this research. Note that the evolution of production in the last two years shows that the future of AI in education will allow establishing more consolidated lines, but as of today it is not.

We can really argue that the production of AI existing so far indicates the evolution of interest in this scientific field under analysis. The first years have an investigation directed to the technological resources, the last ones to the performance and influence of the AI in the didactic processes. This shows a clear evolution on how the integration of AI in the teaching–learning processes is taking place and what aspects educators should be concerned about. In turn, it sets the tone for future research. It can be indicated that AI in the educational field is beginning to be based on pedagogical processes. That is to say, the resources used are not being taken into account. Rather, the teaching and learning process is being developed. This aspect occurs in other areas with the use of other types of technological resources. It is not the fact of using a didactic resource, but rather the way and the process that is followed during its use. For this reason, the methodology applied is also relevant as with the aims of the task will condition the development of the activity and hence the students’ acquisition.

6. Conclusions

This research focused on analyzing the concept of AI from a bibliometric approach based on the analysis of documents indexed in the Web of Science (WoS) database. More specifically, the differentiating aspect of this research resides in the intention of showing the epistemological community of education a documentary analysis with scientific mapping, which constitutes the use of an innovative technique. The dynamic and structural evolution allowed us to obtain interesting results that show how the thematic performance develops in three time periods with their respective diachronic evolutions. In turn, the nature of this research also allowed for showing a conceptual evolution of the theme of this study, with a predominance of the “artificial-intelligence” theme.

The importance and projection of AI in the WoS scientific literature were analyzed with interesting results that allow us to advance in the enunciation of conclusions that did not exist until now due to lack of research in this thematic line. We were able to identify the performance of the scientific production of AI in the field of education in WoS. This allowed us to understand the scientific evolution of AI and discover the most abundant and recurring topics. The mapping allowed us to determine which authors have the most incidents in AI. In fact, these four research objectives were successfully developed, even allowing us to announce that the prospective of this research offers researchers new lines of development around the most relevant topics analyzed. Even the state of the art itself collects the key aspects that other investigations have assumed and the existing gaps, that is, it contributes to the creation of a consolidated base to be able to initiate and develop studies.

Therefore, it can be concluded that AI in education has been studied for many years, more specifically since 1956. However, it is in recent years that this field of study is acquiring relevance, especially in aspects related to student performance. Above all in the application of active teaching methods that allow the development of active and participatory learning in the student.

However, like any research, it has limitations. Specifically, we must refer to the purification of the data presented in WoS, that is, there are repeated documents or even others that do not appear or are not related to the subject of the study. On the other hand, the delimitation of the intervals is questionable and can be improved, because, if we consider equity, there is not a similar number of documents in each of the analyzed intervals. Finally, the use of the parameters was carried out based on the criteria of the researchers of this study, based on an initial search in order to show results based on the quantity and relevance of the study. Therefore, the data that we showed in this research should be analyzed with caution, since, if the parameters of this research are changed, the quantity and the connections could fluctuate in relation to the thematic lines that we have presented. Therefore, as a line of future research, we propose the analysis of various pedagogical methods in the application of AI in higher education. The application of AI in other educational stages can also be analyzed, determining which pedagogical methods are more appropriate according to the age and educational stage of the students.

7. Implications Derived from the Study

It is worth noting that the data collected in this research show a series of implications, applicable to both theory and practice.

7.1. Theoretical Implications

The research carried out contributes to the development of the scientific literature related to AI in the field of education, since it allows us to know the performance of the scientific production indexed in WoS regarding the term “AI”. In addition, the type of study presented allows, in turn, to establish a profile of the type of documents that can be presented, so that future lines of research are more focused. In addition, this study allows us to discover the most decisive issues on AI in WoS and the authors that have had the greatest impact, in addition to identifying the main lines of research of scientists in

each of the established periods. Thus, it also contributes to delimiting the next trends that could be developed in this field of research.

7.2. Practical Implications

The results of this research show how AI is introduced in the field of education. This offers new technological resources and new ways of approaching teaching–learning processes. On the other hand, the development of the evaluation processes constitutes the maximum novelty in terms of AI, since it allows for making decisions and redirecting the didactic processes offering the student active learning. However, using AI in higher education requires training of its teachers and appropriate educational action. This educational technology requires an active and innovative teaching–learning method, with related teaching methodologies. For this, it is necessary to consider how teacher training can be improved and updated, what didactic methods are more related and what potential AI offers us.

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